LETTER

Frame Loss Evaluation of Optical Layer 10 Gigabit Ethernet Protection Switching Using PLZT Optical Switch System*

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SUMMARY Frame loss of the optical layer protection switching using Plumbum Lanthanum Zirconium Titanium (PLZT) optical switch is evaluated. Experimental results show that typically 62 μs guard time is required for commercially available non-burst mode 10 Gigabit Ethernet modules.

key words: *10 gigabit Ethernet, optical switch, protection switching, frame loss*

1. Introduction

IP traffic in the core and access networks increases rapidly by the speed-up of the access network and the spread of the rich applications. 10 Gigabit Ethernet (10 GE) becomes a popular link technology to connect IP routers and Ethernet switches not only intra-office transmission links but also inter-office long reach transmission links. The optical layer protection switching is expected to provide a cost effective link protection mechanism for ultra high speed optical transmission systems such as over 100 Gbps systems. A Plumbum Lanthanum Zirconium Titanium (PLZT) optical switch which provides less than 10 ns switching speed is expected to be applied optical packet switching, optical burst switching, optical slot switching, and optical protection switching. In this paper, evaluation results of PLZT high-speed optical switch based 10 GE optical layer protection switching performance in the Ethernet layer (layer 2) is presented. The frame loss period after protection switching event is measured.

2. Optical Layer Protection Switching

2.1 PLZT Optical Switch System

PLZT high speed optical switch was realized in 2005 [1]. The PLZT optical switch enables to switch its output port with less than 10 ns. Figure 1 shows a PLZT optical switch system developed in our laboratory [2]. The system consists of an optical switch unit and a control unit. The optical switch unit has a high-speed driver, an optical switch body. The controller unit includes a field programmable gate array (FPGA) that has a pair of 4000 pattern memory banks. The memory banks contain switching patterns which are set by commands. The FPGA reads the switching patterns and generates control signals to the high-speed driver. The high-speed driver sends voltage control signals to the PLZT switch body upon receiving signals from the controller board. Memory reading frequency can be set from 1 Hz to 100 MHz. Therefore, switching interval can be set from 20 ns (2 data with 100 MHz reading) to 4000 s (4000 data with 1Hz reading). The memory bank is used to realize an optical slot switching [2], [3].

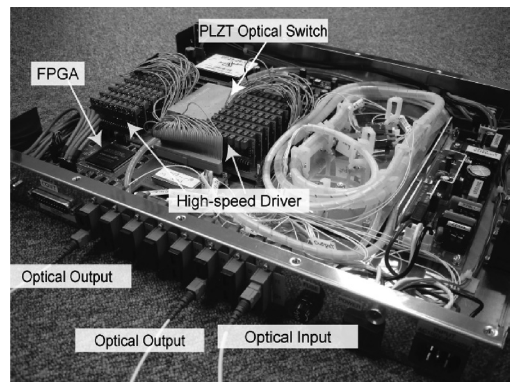

Fig. 1 PLZT optical switch system.

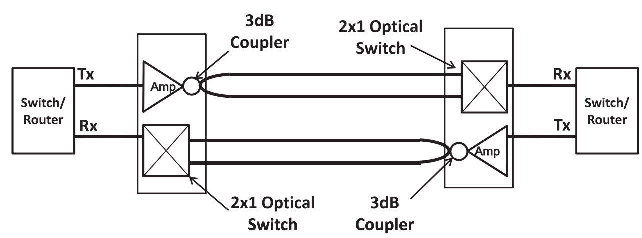

Fig. 2 A generic 1+1 protection switching system architecture model.

2.2 Protection Switch Architecture

A 1+1 dedicated protection switching architecture in the optical layer is discussed and examined in this paper. A generic architecture model of the 1+1 dedicated optical layer protection switching is depicted in Fig. 2. A protection switching system pair is inserted between an Ethernet switch system pair or an IP router system pair. A 3 dB coupler makes a permanent bridge and splits input optical signal. An optical

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switch selects one optical signal as a working path. Another optical signal is called as a protecting path. If signal loss is detected then the protecting path is selected by switch over the optical switch. An optical amp is used to compensate loss of the coupler, loss of the transmission fiber, and loss of the optical switch. To realize bi-direction protection switching, a remote failure indication (RFI) signaling is required. The RFI signaling for 10/40/100 GE is discussed in Sect. 3.2.

3. 10 GE Optical Layer Protection Switching Experiment

3.1 Experimental Set Up

To evaluate the protection switching performance in the 10 GE layer, a simplified protection switch system is used. The experimental protection switch system is shown in Fig. 3. A unidirectional protection switch system is inserted between a 10 GE switch and a personal computer (PC) server (PC2) which is equipped with 10 GE network interface card (NIC). Another PC server (PC1) which is equipped with 10 GE NIC is also connected to the 10 GE switch. Commercially available non-burst mode 10 Gigabit Small Form Factor Pluggable (10 GE XFP) modules are used. PC1 makes IP traffic flow to PC2 via the 10 GE switch.

Automatic periodical switching between a working fiber (select input I1 in Fig. 3) and a protecting fiber (select input I2) is performed by using the memory bank of the PLZT switch system. The switching frequency is set to 10 seconds. Less than 1 μs order of the switching period accuracy is possible in the PLZT switch system.

To evaluate the packet loss performance, UDP/IP traffic was generated at PC1. As a traffic generator, a modified version of "iperf" [4] is used. A 64 bit sequence number and a 64 bit μs order timestamp in the UDP packet of iperf are added for modification. At a receiver side, a sequence number in the received packet is compared with the sequence number of the previously received packet. If a "multiple" packet losses event is detected then the timestamp value is output to indicate the packet loss event time. In the experiment, two types of traffic flows are examined. One is 8,970 byte data size which means 9,000 byte size IPv4 packet. Another is 1,470 byte data size which means 1,500 byte size IPv4 packet. Traffic flow bandwidth is set to 5 Gbps and 2.5 Gbps correspond with 8,970 byte and 1,500 byte respectively. Traffic flow duration is set to 30,000 seconds.

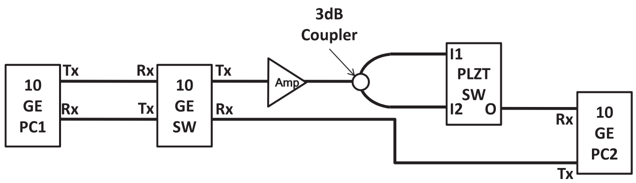

Fig. 3 Experimental protection switching system architecture.

3.2 Experimental Result with Spanning Tree Protocol

A spanning tree protocol (STP) which is popularly used in the current Ethernet is activated at the 10 GE switch. In this environment, when manually switch the PLZT switch port from I1 (working) to I2 (protecting), over 30 seconds UDP packet loss periods is observed even if the loss of link event is not detected at PC2. This means that the link loss event which is not detected at PC2 is detected at the 10 GE switch's receiver (Rx). This causes a topology change event (link deletion and link addition) at the 10 GE switch and therefore STP closes the added link at least 30 seconds.

The topology change is caused by detecting the remote fault and clearing it. A reconciliation sub-layer (RS) [5], which was newly introduced to 10 GE at 2005, of the 10 GE provides these events. RS at PC2 detects the local fault which caused by the switching of the PLZT switch and then inserts remote fault symbols to the data flow to the 10 GE switch. After completing the switching and recovering clock timing and 64B66B code block, RS stops to insert the remote fault symbols and recovering the normal data transmission. RS at the 10 GE switch detects the remote fault event by detecting the remote fault symbols. This event is notified to the STP process as "link deletion." After clearing the remote fault, "link addition" is notified to the STP process. The experimental result shows that STP should be stopped for applying the optical layer protection switching.

The remote fault notification by RS can be applicable as a trigger of the 1+1 bi-directional protection switching. If the protection switch module can monitor a status of RS, a local fault status and a remote fault status can be used as protection switch trigger of the local side protection switch module and the remote side protection switch module respectively.

3.3 Experimental Results without STP

Figure 4 shows a loss period versus multiple loss events characteristic. 1,227 multiple loss events are observed and

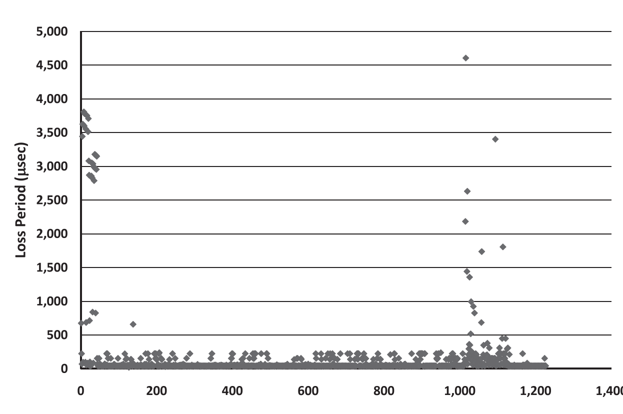

Fig. 4 Frame loss period versus multiple loss events.

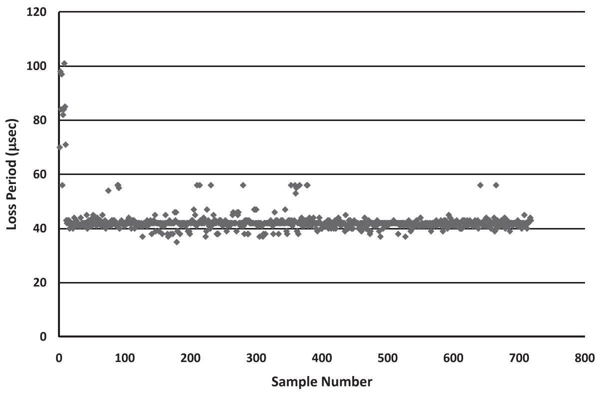

Fig. 5 Frame loss period versus multiple loss events after applying 10 seconds event filter.

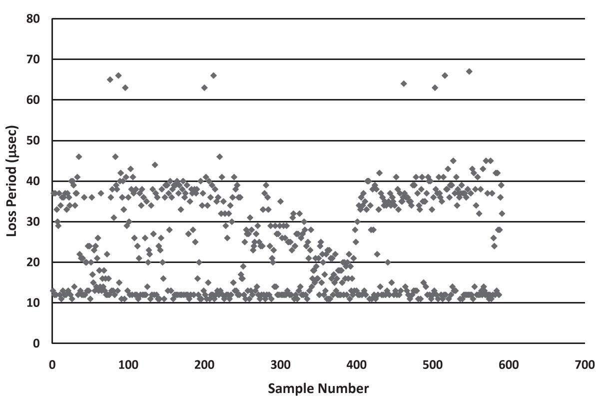

Fig. 6 Frame loss period characteristics (packet size is 1,500 Byte).

maximum 4,606 μs (4.6 ms) loss period is observed. The observed loss events include not only the protection switching loss events but also the frame and packet loss caused by software processing in PCs. Because PC1 and PC2 are operated with Linux OS, there are many processes which can affect the performance of iperf, because the observation time is 30,000 seconds. In many cases, such processes are worked at independent time of the 10 seconds periodical protection switching event. Therefore, such software processing losses can be eliminated by applying 10 seconds event filter which pick up events of exact 10 seconds period. Figure 5 shows the frame loss period versus multiple loss events characteristic after applying the 10 seconds filter. Multiple loss events are reduced from 1,227 to 718 and maximum 101 μs loss period is observed. The mean loss period time is 42.7 μs and the variance was 31.8. Therefore, typically 60 μs (99% value is 59.6 μs) is required for restarting data transmission after the protection switching event. The 60 μs corresponds to 3 frames for 10 GE (9,000 Byte packet size).

1,500 Byte size packets with 2.5 Gbps bandwidth is also examined and results are shown in Fig. 6. Total 591 multiple loss events are observed and the maximum 66 μs loss period is observed. The mean loss period is 24.5 μs and the variance is 150.0. Therefore, typically 62 μs (99% value is 61.2 μs) or 14 frames is required for the guard time.

4. Conclusions

This paper provided the required guard time value after the optical layer protection switching. 62 μs frames loss for commercially available non burst mode 10 GE XFP modules was measured. The frame loss period includes clock recovery time, block code synchronization time, and layer 2 frame synchronization time. The measured value can be applicable to the optical layer protection characteristics and also the guard time of the optical slot switching.

Acknowledgments

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